5030-427

Electric & Hybrid Vehicle System
Research & Development Project

DOE/CS-54209-9
Distribution Category UC-96

Vehicle Test Report: Jet Industries Electra Van 600

Theodore W. Price
Vincent A. Wirth, Jr.

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February 15, 1982

Prepared for
U.S. Department of Energy
Through an Agreement with
National Aeronautics and Space Administration
by
Jet Propulsion Laboratory
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ABSTRACT

The Jet Industries Electra Van 600, an electric vehicle assembled by Jet Industries, Inc., of Austin, Texas was tested at the Jet Propulsion Laboratory's (JPL) dynamometer facility in Pasadena, California and at JPL's Edwards Test Station, located near Lancaster, California. The tests were conducted between May 8, 1979 and January 30, 1980. These tests were performed to characterize certain parameters of the Electra Van 600 and to provide baseline data that can be used for the comparison of improved batteries that may be incorporated into the vehicle at a later time.

The vehicle tests concentrated on the electrical drive subsystem; i.e., the batteries, controller, and motor. The tests included coastdowns to characterize the road load and range evaluations for both cyclic and constant speed conditions. A qualitative evaluation of the vehicle's performance was made by comparing its constant speed range performance with those vehicles described in the document titled, "State-of-the-Art Assessment of Electric and Hybrid Vehicles." The Electra Van 600 range performance was approximately equal to the majority of the vehicles tested in that 1977 assessment.

GLOSSARY

ABREVIATIONS AND ACRONYMS

DOE	Department of Energy
EHV	Electric Hybrid Vehicle
EPA	Environmental Protection Agency
ETS	Edwards Test Station
IDAC	Integrated Data Acquisition and Control
JPL	Jet Propulsion Laboratory
MERADCOM	Mobility Equipment Research and Development Command
SAE	Society of Automotive Engineers
SCR	Silicon-controlled rectifier

ACKNOWLEDGMENT

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CONTENTS

Figures

Tables

SECTION I

SUMMARY

The Jet Industries "Electra Van 600" (Jet Van), an electric vehicle manufactured by Jet Industries located in Austin, Texas, was tested by the Jet Propulsion Laboratory (JPL). Tests were performed using a dynamometer facility at the main Pasadena site, and a runway located near Lancaster, California. The tests, conducted between May 8, 1979, and January 30, 1980, were performed to characterize certain parameters of the Electra Van 600, and to provide baseline data that will be used for the comparison of near-term batteries that may be incorporated into the vehicle. This report presents the results obtained while baseline testing this vehicle with the lead-acid batteries that were supplied by the vehicle manufacturer.

The Jet Van is a conversion of a Japanese-made Fuji van which is not usually sold in the United States. It is capable of carrying a driver and up to three passengers (or a comparable payload). The vehicle was delivered with 17 6-V lead-acid batteries (SGL 211GH-HC) making up the nominal 102-V battery pack which weighs 525 kg (1156 lb). The van has a rear-mounted, series-wound dc motor, and a four-speed manual transaxle coupled to a rear wheel drive. Motor speed control is by means of armature chopping. There is no regenerative braking.

U.S. customary units were used in the collection and reduction of data. The units were converted to the International System of Units for this report. U.S. customary units are presented in parentheses. A summary of the results of the tests is shown in Table 1-1.

Table 1-1. Summary of Electra Van 600 Range Tests

Test	Range, km	Range, mi	Battery Energy, MJ/km	Battery Energy, Wh/mi
56 km/h (35 mi/h)	60.9	37.8	0.587	262
88 km/h (55 mi/h)	39.0	24.3	0.689	308
Driving Schedule "B"	53.8	33.4	0.827	369
Driving Schedule "C"	45.9	28.5	0.785	349
Driving Schedule "D"	29.0	18.0	0.816	365

SECTION II

INTRODUCTION

The vehicle tested and the data presented in this report are in support of the Electric and Hybrid Vehicle (EHV) Act (Public Law 94-413) enacted by Congress on September 17, 1976. A section of this act requires the U.S. Department of Energy (DOE) to promote increased research and development of electric and hybrid vehicles. In consonance with this act of Congress, the DOE awarded contracts for two each of four different vehicles to small business concerns in June 1978. This has become known as the "2 x 4" program.

Acceptance testing of these four vehicles was conducted for DOE at the U.S. Army Mobility Equipment Research and Development Command (MERADCOM) located at Fort Belvior, Virginia. Four duplicate vehicles have been delivered to JPL to be utilized for the assessment of near-term[1] batteries.

The primary purpose of the near-term battery assessment task was to determine "in vehicle" performance of several near-term batteries. Because the emphasis of the task described here was on batteries, the test requirements were structured so that only certain vehicle parameters were characterized. The emphasis was on the battery performance as measured by total energy from the battery under different loads. In addition, the vehicle range, the energy consumed per mile driven, and the energy gained from regeneration (if any) were quantified. Other vehicle parameters such as steering, braking, passenger accomodation, etc. were not characterized. The bulk of the vehicle test effort was devoted to the vehicle-to-battery interface and to the battery performance itself.

The vehicle tests and data presented in this report are part of JPL's Vehicle Test and Evaluation Task in support of the Electric and Hybrid Vehicle (EHV) System Research and Development Project objectives. Both road and dynamometer tests were conducted using JPL procedures which are based on the Society of Automotive Engineers "Electric Vehicle Test Procedures," SAE J227a (Reference 2-1). Results include vehicle driving range at steady speeds and SAE driving schedules.

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[1]For the purposes of this report, near-term means batteries which could be available in commercial quantities in the next 5 years, and which also have the potential for greater capability than batteries currently available.

SECTION III

TEST OBJECTIVE

The objective of the work described here was to perform the tests necessary to characterize the Jet Industries "Electra Van 600" such that a quantitative comparison of vehicle performance could be made if near-term batteries were to be integrated into the vehicle. The tests performed resulted in a determination of range at 56 and 88 km/h (35 and 55 mi/h) and for the SAE J227a B, C and D driving schedules. This vehicle was one of two vehicles in the "2 x 4" group capable of negotiating a "D" cycle.

To aid in accomplishing these objectives, a set of test requirements was formulated using inputs from various groups within JPL's EHV Project. The test requirements were designed so that the primary intent of the testing was to focus on the vehicle-to-battery interface. In doing this, it was expected that a better understanding of the interface would be obtained. Although the primary purpose of the test program was not vehicle performance characteristics, they too were measured.

Measurements of such parameters as range and acceleration profiles of the vehicle in various configurations were acquired so that if the vehicle batteries were replaced with an advanced type, the improvement attributed to the change could be determined. The test requirements were quite rigid in defining the configurations and conditions of the tests to be performed so as to ensure repeatability.

The basic strategy taken in designing the test program to satisfy the objectives was that the majority of the tests would be accomplished on a chassis dynamometer located at JPL. The only tests performed in the field were those necessary to establish the vehicle's road load and hence establish the correct dynamometer settings.

SECTION IV

VEHICLE DESCRIPTION AND OPERATION

The Electra Van 600 (shown in Figures 4-1 and 4-2) is an electric vehicle conversion manufactured by Jet Industries Incorporated of Austin, Texas. The body and running gear are from Fuji heavy industries of Japan; the internal combustion (I.C.) engine version of this vehicle is not imported to the United States.

Seventeen lead-acid traction batteries are located under the rear bench seat in an internally mounted steel battery box with a polyethylene liner. In addition to the traction batteries, a 12-V deep-discharge accessory battery is located in the same compartment. There is no provision made to charge the accessory battery during vehicle operation. The battery compartment has a forced-air ventilation system to carry away heat and any gases generated during battery operation.

The vehicle is propelled by a specially designed 7-in. frame, series-wound motor with high temperature class "H" insulation. The motor is manufactured by the Prestolite Division of the ELTRA Company. The manufacturers continuous power rating of this motor is 16.4 kW (22 hp). During test of the vehicle it was found that this rating was somewhat optimistic. (A brief discussion of the events leading to this conclusion can be found in Section VIII of this document.) The motor is directly coupled at the clutch interface to the four-speed manual transmission normally used in the I.C. version of this vehicle. The only change to the stock drive train was to change the mechanical clutch linkage to a hydraulic system that would accommodate the increase in pressure-plate force that was necessary to couple the higher torque electric motor to the transmission.

The motor controller is a General Electric silicon-controlled rectifier (SCR) type EV1-C which does not accommodate regenerative braking. The controller is enclosed in a sheet metal box that is located adjacent to the motor in the rear engine compartment of the vehicle.

As originally configured both the motor and controller were air cooled by a 12 V, 47.2 ℓ/s (100-ft^3/min) centrifugal blower which was mounted above the transmission. The motor incorporates an internal centrifugal fan mounted on the armature shaft. A bimetal over-temperature switch is located internal to the case. The set point is nominally 110°C (230°F). The field poles are not laminated in this motor. (see Section VIII for a brief description of modifications made by JPL to the cooling circuits.)

The vehicle has an onboard battery charger manufactured by the Lester Electrical Company (Model 9458). It is capable of both 115 V and 230 V 60 Hz ac input and has outputs for the main battery pack and the accessory battery. The unit is located just behind the rear bumper of the vehicle (Figure 4-3). It was not used during JPL testing because of its inability to charge the pack in the controlled manner considered necessary to achieve test repeatability.

The vehicle specifications are summarized in Table 4-1.

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Figure 4-1. Electra Van 600--Left Front View

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Figure 4-2. Electra Van 600--Left Rear View

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Figure 4-3. Electra Van 600 On-Board Battery Charger

Table 4-1. Electra Van 600 Vehicle Specifications

Vehicle Weight, kg (lb)	
Gross weight	1542 (3400)
Curb weight	1292 (2850)
Driver weight	68 (150)
Payload weight	181 (400 without passengers)
Vehicle Size, cm (in.)	
Wheelbase	183 (72)
Length	343 (135)
Width	140 (55)
Headroom	86 (34)
Legroom	91 (36)
Transmission Type	4-speed manual transaxle
Gear ratio	1st: 4.36, 2nd: 2.62, 3rd: 1.80, 4th: 1.107
Differential ratio	5:11
Propulsion Batteries (Lead-Acid)	
Number	17
Manufacturer	SGL
Nominal pack voltage	102 V
Ampere-hour capacity	138 @ c/3 rate
Battery weight, kg (lb)	524 (1156)
Controller	
Type	Silicon-controlled rectifier Armature Chopper
Manufacturer & model	General Electric EV1-C
Voltage rating	102 V
Current rating (amp)	550 A
Weight, kg (lb)	21 (48)
Propulsion Motor	
Type	Series dc
Manufacturer	Prestolite
Insulation class	H
Voltage rating	102 V
Current rating (amp)	205 A peak
Power rating, kw (hp)[a]	16.4 (22)
Size diameter, cm (in.)	18.4 (7.25)
Weight, kg (lb)	47.6 (105)
Rated speed, rpm	4350
Maximum speed, rpm	5750

[a]Rated at 22 hp; see text for results.

Table 4-1. (Cont'd)

Body	
Type	Steel mini van
Manufacturer	Fuji Heavy Industries (Japan)
Number of doors (type)	3 (hinged) + 2 sliding
Number of windows (type)	4 (fixed) + 2 (roll down) 2 (sliding)
Number of seats (type)	2 (bench)
Cargo volume, m^3 (ft^3)	2.29 (81)
Brake Type	
Front	Drum
Rear	Drum
Tire Type	Steel-belted radial
Manufacturer	Pirelli
Size	155 SR 12
Pressure (psig)	40
Rolling radius, cm (in.)	27.28 (10.742)

An "Espar" diesel fuel-fired hot air heater was incorporated in the vehicle to replace the hot water system normally used. The original fuel tank was used by this heater.

SECTION V

TEST METHODOLOGY

For the purposes of this report, testing was divided into two general categories: track and chassis dynamometer. Very limited track tests, consisting only of coastdowns, were conducted primarily for the purpose of establishing dynamometer settings. The chassis dynamometer tests consisted of range at constant speeds of 56 km/h (35 mi/h) and 88 km/h (55 mi/h), and driving the J227a schedules B, C, and D.

A more detailed discussion of the test methodology used for the "2 x 4" Program may be found in a companion report, Reference 5-1. The discussion included here is, in general, limited to those items unique to the Electra Van 600.

JPL operates a test facility at the Edwards Air Force Base which is located near Lancaster, California. At this facility, known as Edwards Test Station (ETS), JPL has access to a semi-active Air Force runway 1829 m (6000 ft) in length. This facility was used for the coastdown testing.

The steady speed range and cyclic range tests were conducted in the chassis dynamometer portion of the JPL Automotive Test Facility. A twin-roll Clayton dynamometer with 0.218 m (8.6 in.) diameter rollers and direct-drive inertia weights available in 57 kg (125 lb) increments was used in the dynamometer tests. This dynamometer is of the type used by the Enviromental Protection Agency (EPA) for Exhaust Emission Certification testing.

The dynamometer used at JPL can be set to simulate the aerodynamic load at any arbitrary value of vehicle speed. The loads at other speeds are then determined by the nominally cubic variation of load as a function of vehicle velocity that is built into the dynamometer. In addition, the tire pressure and/or the tire loading (vehicle weight on the drive wheels) were manipulated within limits, to control the tire/roller losses.

A. ROAD LOAD DETERMINATION AND DYNAMOMETER LOAD ADJUSTMENT

Determination of road load power requirements is a standard test specified in the SAE Test Procedure J227a. However, the intent of that procedure is to define road load for reporting purposes, while in the context of this report, road load was established primarily for defining dynamometer adjustments.

After the road load determination was completed by coastdown testing at ETS, the vehicle was next moved to the dynamometer and the coastdown process was repeated on the dynamometer. First, the time required to coast from 32 to 16 km/h (20 to 10 mi/h) was matched to the track time by adjusting the tire pressure and/or tire loading. Over this velocity increment the aerodynamic portion of the total road load is small and the necessary tire adjustments are not masked by the aerodynamic variable.

Once the 32 to 16 km/h (20 to 10 mi/h) coastdown time is matched, the aerodynamic load is adjusted by means of the water brake absorber portion of

the dynamometer. This was generally done by matching the coast time between 88 and 72 km/h (55 to 45 mi/h), but can, in principal, be done at any velocity. As high a speed as practical is used so that the aerodynamic load is as large a part of the total as possible. Again, the time to coast between two speeds is matched to that obtained during the track test. The 32 to 16 km/h (20 to 10 mi/h) coastdown is repeated and the tire pressure/loading is adjusted if necessary. The two coastdowns were alternately performed until the two road times were matched as closely as possible.

After the "road" coastdown times have been duplicated on the dynamometer, the resultant aerodynamic horsepower at 80 km/h (50 mi/h) was measured. Note that this is the first time that a power value has been quantified and note further that quantification is not necessary to the process, however, the dynamometer is adjusted to this specific horsepower value before each subsequent test of the vehicle. A more detailed description of the coastdown and dynamometer processes may be found in Reference 5-1.

B. CHASSIS DYNAMOMETER INSTRUMENTATION

A relatively large (Figure 5-1) general purpose Integrated Data Acquisition and Control (IDAC) data system is an integral part of the JPL Automotive Test Facility (see References 5-1 and 5-2). The digital recording system is used to record data for all tests conducted on the chassis dynamometer. Approximately 40 data channels are routinely recorded. The energy data (in digital format) and each analog channel are sampled at a rate of approximately 10 times per second.

Data recording is accomplished in two ways: real time high-speed printer and magnetic tape. The bulk of the recording is done with the magnetic tape while the direct printing is used for a "quick look" immediately after test completion. Subsequent data reduction of the magnetic tapes provides a detailed tabular printout of the data as well as plots of pertinent parameters.

Intervals of high-speed data are acquired at various times during a test. The exact time within the test depends on the type of test. For instance, during constant-speed tests, a 1 s interval of data is recorded once every 60 s. During the driving schedule tests, the 60 s interval data are supplemented by several longer recordings. Continuous recording of two complete repetitions of a driving cycle (Figure 5-2) are made. This strategy allows characterization of the vehicle transient performance at different depths of battery discharge. These continuous recordings are intended to occur at 0%, 40%, 80%, and 100% levels of battery depth of discharge. However, the time at which these levels of depth of discharge occur must be estimated in advanced of the test. Therefore, the designations 0%, 40%, 80%, and 100% depth of discharge are only approximate. During some tests, the continuous recording at 100% depth of discharge was missed altogether because of a combination of the estimating process and the very rapid decay in battery voltage as 100% depth of discharge is approached.

The key measurements were those of voltage, current, energy, and power for the battery and motor armature, motor and drive shaft rotational speed, vehicle velocity, total distance traveled, and battery electrolyte temperature. Each of these is discussed in more detail in Reference 5-1, and a brief discussion is included below.

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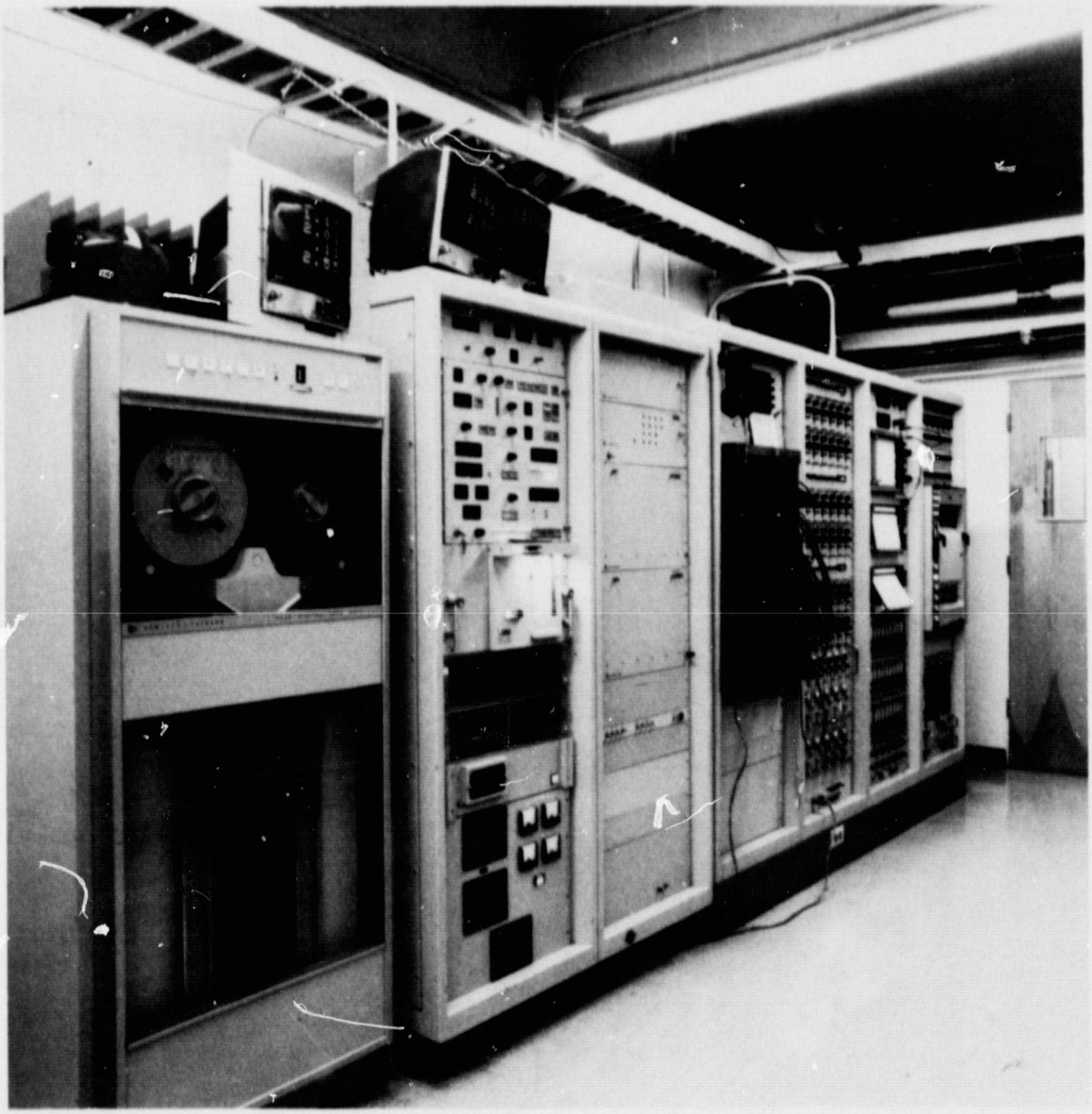

Figure 5-1. Central Instrumentation Area

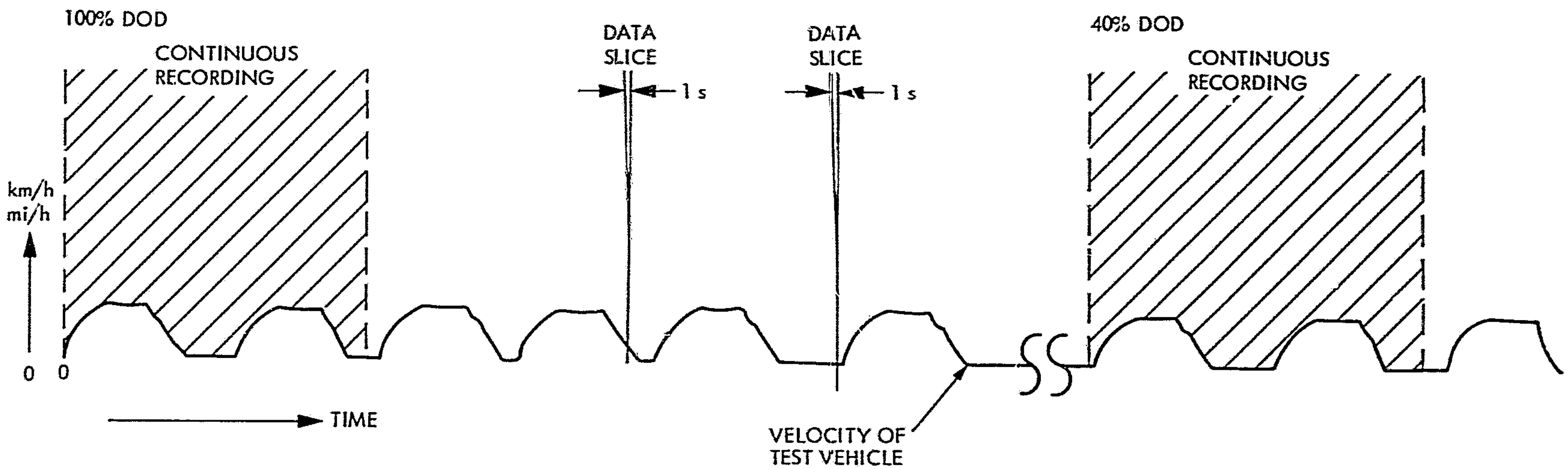

Figure 5-2. Typical Data Recording Format

1. Power Measurements (voltage, current, energy)

The power measurement system uses signals proportional to voltage and current, multiplies the current and voltage signals and provides digital output signals proportional to bipolar power. Analog signals of the input current and voltages are also available. These analog signals are isolated from common-mode voltages and include both sideband (approximately 50 kHz) and filtered (approximately 10 Hz) output signals. The 50-kHz response outputs are primarily used for checkout, investigation of waveforms, and related activities. The low frequency signals are connected to the test facility's data system to provide recorded data of both voltage and current. The output signals proportional to power are integrated by mechanical counters and both recorded directly and integrated by the digital data system. A more detailed description of the power measurements is included in Reference 5-2.

2. Motor and Drive Rotational Speed

During dynamometer testing, only the rotational speed of the drive shaft was recorded and the motor speed inferred. (No convenient access for installation of speed pickup on motor.) Alternating strips of reflective and black tape were placed on the drive shaft. A photo optical sensor was used to monitor the black-to-reflective tape transitions and thus provide a signal proportional to the drive shaft rotational speed.

3. Vehicle Velocity and Distance Traveled

Each of the two dynamometer rolls is equipped with a digital transducer which produces a pulse proportional to each centimeter of distance traveled. These pulses are recorded as a rate (miles per hour) and integrated with a counter to give total distance (miles). Although the pulse signals from both dynamometer rolls are recorded, only the data on the idle roll are used for reporting purposes. Data from the other dynamometer roll (absorption roll) are used for engineering information and to adjust the dynamometer aerodynamic load simulation.

4. Torque and Aerodynamic Horsepower

The reactive torque which results from energy being dissipated in the dynamometer absorption unit is measured by a precision load cell. The torque measurement and dynamometer rotational speed are combined by the IDAC data system to calculate horsepower in near real time (within 0.1 s). This permits accurate adjustments of the dynamometer aerodynamic horsepower.

5. Miscellaneous Measurements

Additional recorded measurements include battery temperature, motor case temperature, atmospheric pressure, calibration voltages, and several other parameters.

C. VEHICLE CONDITIONING AND WARM-UP

No vehicle warm-up was performed before the dynamometer range and acceleration tests. However, a warm-up was performed prior to all road load determination (coastdown) testing at ETS and before the companion chassis dynamometer coastdowns. The warm-up at ETS was accomplished by towing the vehicle up and down the length of the runway at 40 to 56 km/h (25 to 35 mi/h) for approximately 20 km (12 mi). The purpose of this warm-up period was to bring the vehicle lubricants, wheel bearings, and tires to their normal operating temperatures.

Before each dynamometer range test, the vehicle was temperature conditioned. The primary purpose of this temperature soak was to ensure that the battery electrolyte temperature was 21 $\pm$2.8°C (70 $\pm$5°F).

D. DYNAMOMETER TEST PREPARATIONS

A dynamometer warm-up was conducted prior to vehicle testing in the following manner. The 1530 kg (3375 lb) inertia weight setting corresponding to the Electra Van 600 was coupled to the dynamometer rollers. An ICE-powered vehicle was operated on the dynamometer for 5 min at 80 km/h (50 mi/h) and an additional 5 min at 56 km/h (35 mi/h). The warm-up vehicle was then operated at a constant speed of 80 km/h (50 mi/h) and the dynamometer adjusted to the specific horsepower value required by the Electra Van 600 (see pages 5-1 and 5-2). Immediately following the warm-up, the test vehicle was winched onto the dynamometer. No test vehicle warm-up was performed prior to dynamometer testing.

Range at steady speed was performed as specified in the SAE Test Procedure J227a. Driving schedule tests were performed using the SAE J227a with additional JPL definition. The details of the additional JPL definition may be found in Reference 5-1.

E. TEST TERMINATION CRITERIA

Multiple test termination criteria were used depending on the nature of the test; i.e., constant speed or cyclic. Constant speed tests were ended when: (1) the battery pack voltage decayed to an average of 1.3 V/cell for more than 5 s (66 V for the total battery pack), (2) the batteries or motor temperature exceeded the limit specified by the manufacturer, or (3) the vehicle speed could not be maintained within 95% of the specified velocity. Criteria (1) and (2) were also employed for the cyclic tests, but a different velocity criteria was used. These tests were terminated when the acceleration portion of any cycle could not be completed within 2 s of the time specified by the procedure. With the exception of those tests in which motor/controller over temperature occurred, the constant speed tests were terminated by the battery voltage criteria, while the cyclic tests were ended when the vehicle could no longer complete the acceleration ramp in the allotted time.

SECTION VI

TEST HISTORY

A. PRE-TEST ACTIVITIES

The Electra Van 600 was received at the Jet Propulsion Laboratory on May 6, 1979. Total mileage on the odometer was 11.6 mi. The next several weeks were spent configuring the vehicle for the testing phase. Tow bumpers, fifth wheel bracket, instrumentation bench, temperature transducers, etc., were installed and functionally verified. A simplified schematic of the vehicle system illustrating the location of power/energy measurement points is given in Figure 6-1.

Upon receipt of the vehicle at JPL, a safety inspection was performed prior to the instrumentating and testing of the vehicle to ensure that the vehicle was safe for testing purposes. It was verified that: the battery terminals were covered, all points of high voltage were shielded from accidental human contact, the propulsion system was electrically isolated from the vehicle chassis, the batteries were adequately constrained, the conventional safety equipment (horn, lights, turn indicators, etc.) operated properly, the battery compartment ventilation system functioned properly, etc.

Prior to start of the test phase, the wheel bearings and suspension were inspected and lubricated. All wheels were balanced and aligned according to the manufacturer's specifications. The vehicle was weighed and the load distribution between the front and rear axles was established. The weight of the vehicle was 1292 kg (2850 lb). The additional weight required to bring the vehicle to the manufacturer's recommended gross vehicle weight of 1542 kg (3400 lb) was determined.

Modifications performed on the vehicle at JPL to prepare for testing consisted of the following:

The existing front bumper was replaced with one of special design for the Jet Van. This heavy-duty bumper allows for the safe towing of the vehicle at high speeds. Quick disconnect connectors were installed between the battery pack and the motor/controller. This provided a safe way to isolate the batteries from the motor and controller during maintenance and repair, and also allowed a convenient place to connect facility batteries for non-performance test operations. Current sensors (shunts) were installed on the negative cable side of the battery pack, the motor armature, and the external battery charger that was used during the test program. The reason for the external charger was two-fold: (1) the onboard charger was not capable of charging the pack in sufficient time to satisfy the test schedule, and (2) the charging profile could not be accurately controlled with the internal charger.

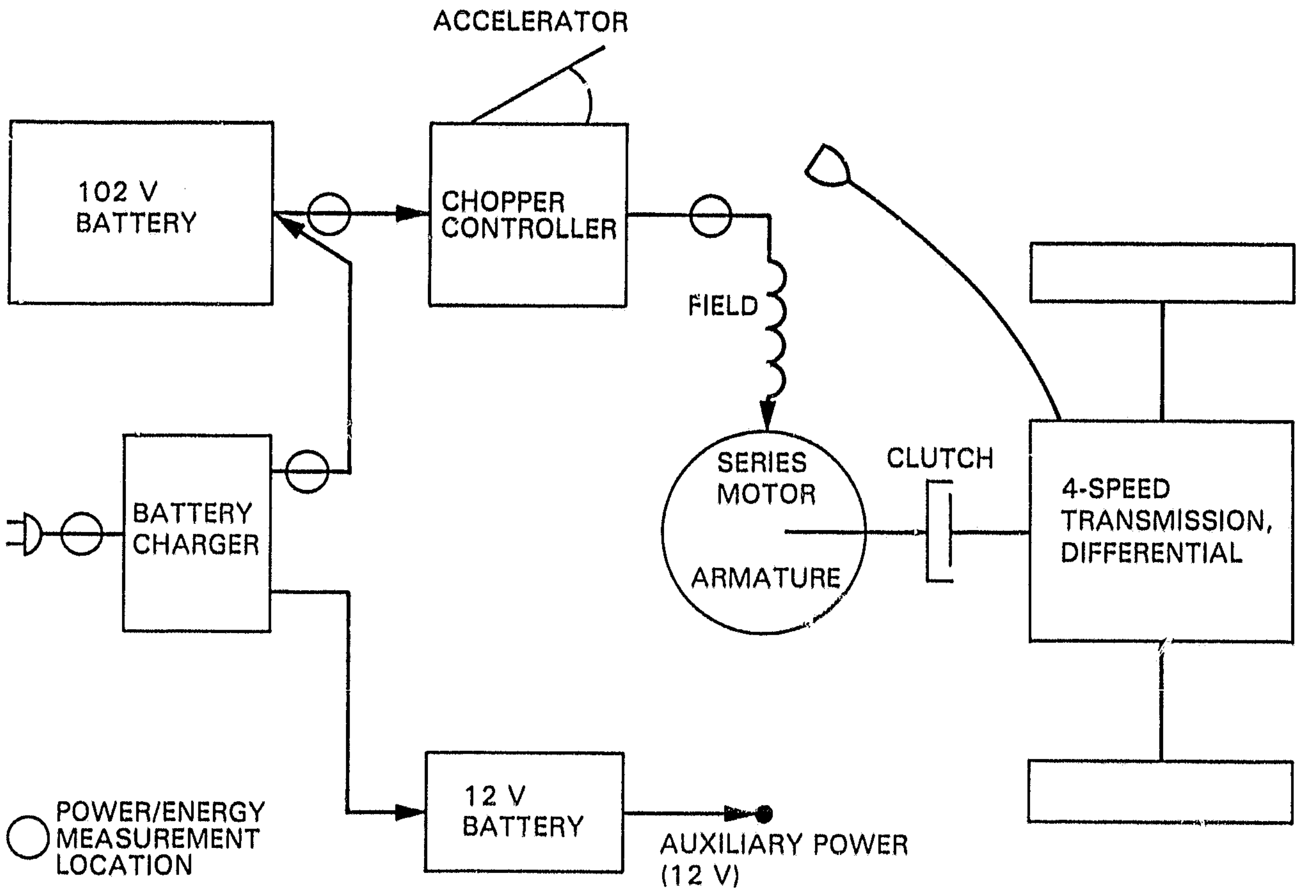

Figure 6-1. Schematic of Electra Van 600 Drive Train

B. BATTERY CHARGING

The standard charging profile that was followed for charging the battery used the guidelines below:

(1) Charge at a constant 25 A rate until the battery pack terminal voltage is equal to an average 2.7 V/cell [corrected to 26°C (80°F)].

(2) The temperature correction factor used was to subtract 4 mV/cell for each degree F over 80°F, and add 4 mV/cell for each degree F under 80°F.

(3) When the pack voltage of 137.7 V (2.7 V/cell x 51 cells) was reached, the charger current was allowed to taper while the voltage was held at its temperature-corrected value for 6 h.

A typical battery charge is illustrated in Figure 6-2.

After battery charge termination the vehicle was allowed to soak in a temperature controlled room until the average battery electrolyte temperature stabilized at 21 ± 2°C (70°F). An entire day was specifically set aside between each test day for temperature stabilization.[2] Even with this extra "soak" day, forced convection cooling of the batteries was employed to satisfy the 21°C (70°F) test criterion within the allocated test time.

C. COASTDOWN TESTS

The Electra Van 600 was transported to Edwards Test Station and the limited instrumentation required for the coastdown tests was installed. After completing the installation of all instrumentation, the van was again weighed. The weight was 3160 lb. To load the van to a total test weight of 3400 lb, a ballast of 80 lb (in addition to the driver's weight) was added to the vehicle, distributed in such a manner as to maintain the original front/rear axle load distribution.

A total of 20 high-speed and 20 low-speed coastdown tests were conducted. A detailed analysis of the coastdown data is presented in Section VII, Test Results.

During the dynamometer portion of the coastdown process, while the vehicle was being moved off of the dynamometer, the transmission failed. The failed transmission was replaced with a new unit, however, there was concern that because of the transmission change, the vehicle's rolling resistance might

[2]The final (equalization) portion of battery charging resulted in self-heating of the batteries to the point that they typically gained 10° to 15°C (18° to 29°F). The final electrolyte temperature was then in excess of 38°C (100°F).

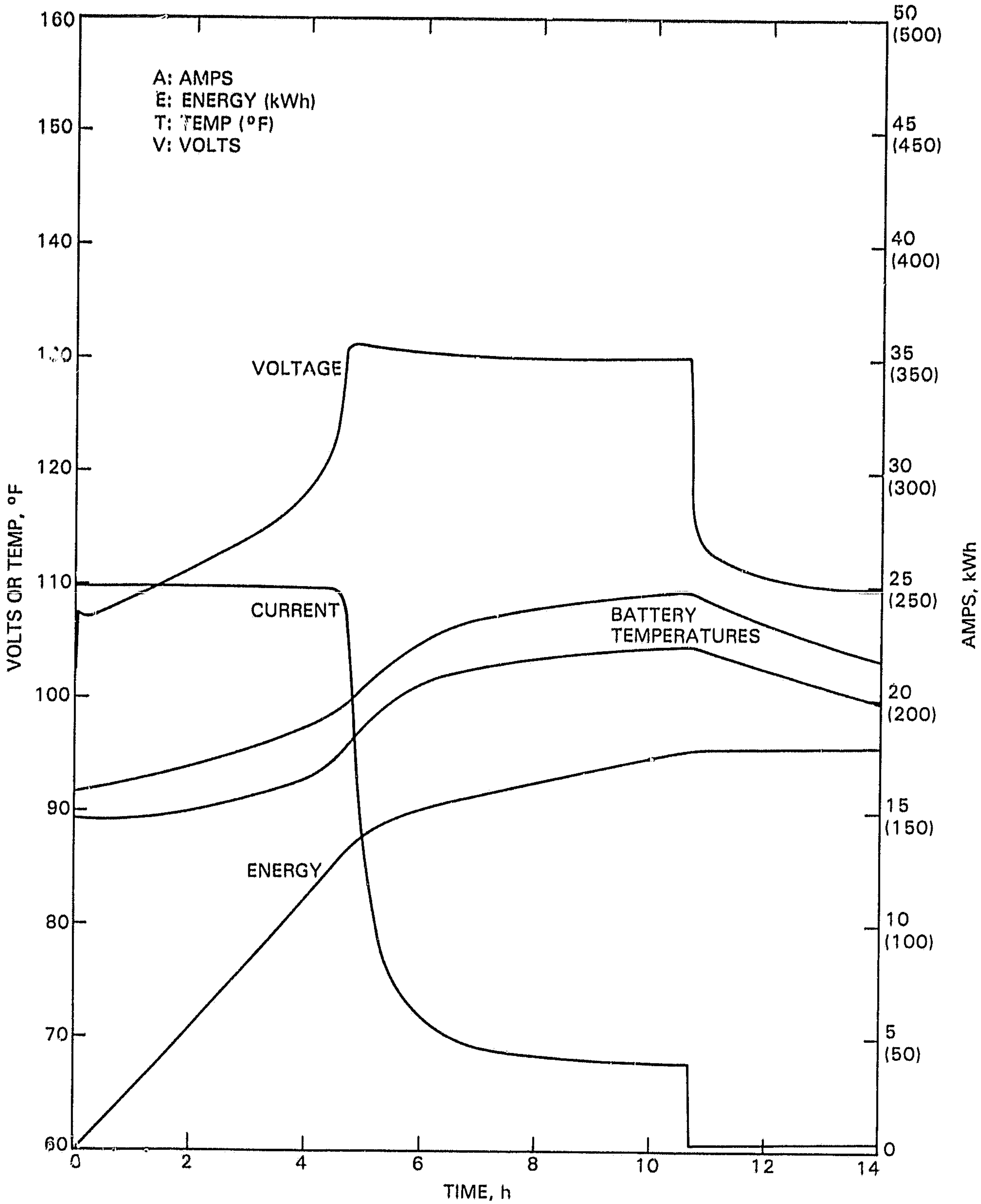

Figure 6-2. Electra Van 600 Battery Pack Recharge

have changed, possibly making the runway coastdowns invalid. Sufficient dynamometer coastdown data had been obtained with the old transmission so that changes, if any, could readily be detected. There was no detectable change in rolling resistance as a result of the transmission change.

SECTION VII

TEST RESULTS

This section presents the results of the dynamometer testing and the road energy and power requirements. These tests were of three major types: range at constant speed, range under the SAE J227a driving schedules B, C, and D, and road load determination tests, previously discussed. The results are presented in separate subsections with a corresponding summary table of pertinent test data. All test data were recorded in customary U.S. units, but are reported in this section in both S.I. (metric) and U.S. units. Appendix A is a summary of the dynamometer test data.

A. RANGE AT CONSTANT SPEED TESTS

Due to the limited length of the runway, no constant speed tests were performed at the ETS facility. Two 88 km/h (55 mi/h) and three 56 km/h (35 mi/h) constant speed tests were conducted on the dynamometer at the JPL Automotive Test Facility. Speed was held constant to within ±5% of the nominal value and the tests were terminated when either the battery pack voltage fell below 66 V (1.3 V/cell), or the vehicle speed could not be held to within 5% of the nominal value. The 88 km/h (55 mi/h) and 56 km/h (35 mi/h) test data are shown in Tables 7-1 and 7-2, respectively.

In the limited number of steady-state tests performed, the repeatability was satisfactory although the difference between the largest and smallest ranges at 56 km/h (35 mi/h) was 6.4% and 9.3% for the 88 km/h (55 mi/h) tests.[3] Battery electrolyte temperature, as reflected by the end-of-test temperature, is a known contributor to range variation. The "rule of thumb" which has been found to be reasonably accurate for lead-acid batteries is that a 1% change in battery energy capacity may be expected for each 1°C in electrolyte temperature. Therefore, a 5% difference in battery energy and range between the two 88 km/h (55 mi/h) tests and 1.5% difference for the 56 km/h (35 mi/h) tests could be expected. The difference in battery energy was 9% for the 88 km/h (55 mi/h) (with a corresponding 9% increase in range). However, in the case of the 56 km/h (35 mi/h) tests the difference in battery energy and range are in the opposite direction and hence cannot be explained by electrolyte temperature. Thus, the variations in range cannot be explained solely by variations in electrolyte temperature.

B. DRIVING CYCLE RANGE TESTS

To establish uniform procedures for the testing of an electric vehicle, i.e., stop-and-go driving, the Society of Automotive Engineers (SAE) has established four driving schedules for electric vehicles. These schedules exercise the vehicle in a near "normal manner" (i.e., accelerate, cruise, coast, brake and idle), but also lead to test repeatability and standardization. The exact requirements of these cycles are presented

[3]Neglecting Test 5 which was prematurely terminated because of over-temperature.

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Table 7-1. Electra Van 600 — 86 km/h (55 mi/h) Constant Speed Range Results

U.S. Customary Units

Test No.	Range, mi	Cycles Driven	Battery Energy, kWh		Battery Energy Economy, kWh/mi	Battery Energy Recharge, kWh	Battery, Ah		Battery[a] Temperature, °F	
			Out	In (Regen)			Test	Recharge	Pre-Test	Post-Test
13[b]	23.09	--	7.124	--	0.309	13.263	79.53	111.05	65.8	82.2
15[b]	25.45	--	7.841	--	0.308	13.853	87.15	117.26	74.0	90.4

S.I. Units

Test No.	Range, km	Cycles Driven	Battery Energy, MJ		Battery Energy Economy, MJ/km	Battery Energy Recharge, MJ	Battery, Ah		Battery[a] Temperature, °C	
			Out	In (Regen)			Test	Recharge	Pre-Test	Post-Test
13[b]	37.15	--	25.65	--	0.690	47.75	79.53	111.05	18.7	27.8
15[b]	40.95	--	28.23	--	0.689	49.87	87.15	117.26	23.3	32.4

[a]Average of five (5) instrumented batteries.
[b]Tests terminated when vehicle was unable to maintain the speed to within 5%.

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Table 7-2. Electra Van 600 -- 56 km/h (35 mi/h) Constant Speed Range Results

U.S. Customary Units

Test No.	Range, mi	Cycles Driven	Battery Energy, KWh		Battery Energy Economy, KWh/mi	Battery Energy Recharge, KWh	Battery, Ah		Battery[a] Temperature, °F	
			Out	In (Regen)			Test	Recharge	Pre-Test	Post-Test
5[b]	14.20	--	3.938	--	0.277	c	43.73	c	72	81.0
10[d]	39.10	--	10.156	--	0.259	17.669	116.5	150.6	71	87.6
14[d]	36.58	--	9.710	--	0.265	16.559	109.5	141.3	72	95.2

S.I. Units

Test No.	Range, km	Cycles Driven	Battery Energy, MJ		Battery Energy Economy, MJ/km	Battery Energy Recharge, MJ	Battery, Ah		Battery[a] Temperature, °C	
			Out	In (Regen)			Test	Recharge	Pre-Test	Post-Test
5[b]	22.85	--	14.18	--	0.621	c	43.73	c	22.2	--
10[d]	62.92	--	36.56	--	0.581	63.61	116.5	150.6	21.6	30.8
14[d]	58.86	--	34.96	--	0.594	59.61	109.5	141.5	22.2	32.3

[a]Average of five (5) instrumented batteries.
[b]Tests terminated due to over-temperature warning buzzer.
[c]Recharge data not recorded due to equipment problems.
[d]Test terminated due to low voltage criteria (66 V).

in Section VI of the SAE J227a document: "Electric Vehicle Test Procedure." Additional definition has been added to these driving schedules for the purpose of the JPL tests. The form of the cycles used at JPL are described in Reference 5-1. Two schedule Ds, two Cs, and four B tests were completed at the JPL dynamometer facility. All tests were terminated as a result of the vehicle being unable to match the acceleration ramp in the prescribed time except for Tests 2 and 3 (B cycles), which were terminated because of the motor/controller overtemperature problem noted in Section VIII.

Table 7-3 summarizes the results of the Schedule B cycle tests. Tests 4 and 9 were the only two terminated by battery depletion, and the range variation time between these two tests was only 2.1%. Because the post-test battery temperature was not recorded on Test 9, a comparison of this parameter between the two tests is not possible.

Table 7-4 summarizes the results of the Schedule C cyclic tests. Here, a 5.7% variation in range occurred where only a 2^{o}C variation in final battery temperatures was noted. This larger-than-expected variation in range suggests that factors other than battery electrolyte temperatures may have been present.

Table 7-5 summarizes the results of the Schedule D cyclic tests. The 7.3% variation in range between Tests 11 and 12 was undoubtedly due in large part to the absence of dynamometer warm-up prior to Test 11, as the final battery temperatures were almost identical for both tests.

C. ENERGY CONSUMPTION

Energy consumption and road power requirements were determined using methods similar to those given in SAE Test Procedure J227a, Section 10, Vehicle Road Energy Consumption. For the SAE procedure, three pairs of the coastdown tests are averaged for the full velocity profile. The data from Table 7-6 are an average of 16 separate coastdown tests (i.e., 8 pairs). The results of the calculations represent the energy required by the vehicle to overcome aerodynamic and rolling resistance losses, including part of the transmission energy losses. This is not the energy needed from the vehicle batteries to propel the vehicle at various speeds. The battery, controller, motor, and a majority of the transmission energy losses are excluded from the energy consumption values reported here.

Table 7-6 is a tabulation of the time increment required to coast between each of the velocity increments listed. Figure 7-1 shows the same data graphically. After plotting the data from Table 7-6 the curve of Figure 7-1 was fitted to provide some smoothing. "Smoothed" values of time were read from this curve and are included in Table 7-6. The smoothed values were used in the subsequent calculations of road energy and power. The road power and energy consumption were calculated using the appropriate equations from SAE Procedure J227a. The results of these calculations are given in Table 7-7 and are plotted in Figures 7-2 and 7-3.

Table 7-3. Electra Van 600 -- Schedule "B" Cycle Range Results

U.S. Customary Units										
Test No.	Range, mi	Cycles Driven	Battery Energy, kWh		Battery Energy Economy, kWh/mi	Battery Energy Recharge, kWh	Battery, Ah		Battery[b] Temperature, °F	
			Out	In (Regen)			Test	Recharge	Pre-Test	Post-Test
2[a]	13.4	65	5.067	--	0.378	10.650	55.9	86.6	71	85.0
3[c]	25.7	125	9.57	--	0.372	16.865	104.3	141.1	72	83.0
4[d]	33.8	163	12.29	--	0.363	19.992	139.2	170.5	74	92.8
9[e]	33.1	161	12.45	--	0.376	20.259	140.0	174.8	71	f
S.I. Units										
Test No.	Range, km	Cycles Driven	Battery Energy, MJ		Battery Energy Economy, MJ/km	Battery Energy Recharge, MJ	Battery, Ah		Battery[b] Temperature, °C	
			Out	In (Regen)			Test	Recharge	Pre-Test	Post-Test
2[a]	21.56	65	18.24	--	0.846	38.34	55.9	86.6	21.6	26.6
3[c]	41.35	125	34.45	--	0.833	60.71	104.3	141.1	22.2	28.3
4[d]	54.39	163	44.24	--	0.813	71.97	139.2	170.5	23.3	33.7
9[e]	53.26	161	44.82	--	0.842	72.93	140.0	174.8	21.6	f

[a]Test terminated due to high motor temperature.
[b]Average of five (5) instrumented batteries.
[c]Test terminated due to high motor temperature induced current limit.
[d]1. A separate blower was added to cool the motor prior to this test. The original blower is now cooling the controller only.
2. Second gear only was utilized for this test.
3. Test terminated due to the low voltage criteria (66 V).
[e]1. Second gear only was utilized for this test.
2. Test terminated due to the low voltage criteria (66 V).
[f]Not recorded.

Table 7-4. Electra Van 600 — Schedule "C" Cycle Range Results

U.S. Customary Units										
Test No.	Range, mi	Cycles Driven	Battery Energy, kWh		Battery Energy Economy, kWh/mi	Battery Energy Recharge, kWh	Battery, Ah		Battery[a] Temperature, °F	
			Out	In (Regen)			Test	Recharge	Pre-Test	Post-Test
16[b]	27.68	78	9.714	--	0.350	17.279	116.25	147.73	67.5	92.4
17[b]	29.34	82	10.288	--	0.349	17.490	117.99	151.0	71.2	96.2
S.I. Units										
Test No.	Range, km	Cycles Driven	Battery Energy, MJ		Battery Energy Economy, MJ/km	Battery Energy Recharge, MJ	Battery, Ah		Battery[a] Temperature, °C	
			Out	In (Regen)			Test	Recharge	Pre-Test	Post-Test
16[b]	44.54	78	34.97	--	0.785	62.20	116.25	147.73	19.7	33.5
17[b]	47.21	82	37.04	--	0.785	62.96	117.99	151.0	21.7	35.6

[a]Average of five (5) instrumented batteries.
[b]Tests terminated when vehicle was unable to meet the acceleration ramp.

Table 7-5. Electra Van 600 -- Schedule "D" Cycle Range Results

U.S. Customary Units										
Test No.	Range, mi	Cycles Driven	Battery Energy, kWh		Battery Energy Economy, kWh/mi	Battery Energy Recharge, kWh	Battery, Ah		Battery[a] Temperature, °F	
			Out	In (Regen)			Test	Recharge	Pre-Test	Post-Test
11[b,c]	13.09	13	5.193	--	0.397	10.830	58.74	89.82	74.8	88.6
12[b]	18.00	18	6.569	--	0.365	12.668	75.28	106.08	70.6	89.0
S.I. Units										
Test No.	Range, km	Cycles Driven	Battery Energy, MJ		Battery Energy Economy, MJ/km	Battery Energy Recharge, MJ	Battery, Ah		Battery[a] Temperature, °C	
			Out	In (Regen)			Test	Recharge	Pre-Test	Post-Test
11[b,c]	21.06	13	18.69	--	0.887	38.99	58.74	89.82	23.7	31.4
12[b]	28.96	18	23.64	--	0.816	45.60	75.28	106.08	21.4	31.6

[a]Average of five (5) instrumented batteries.
[b]Tests terminated when vehicle was unable to meet the acceleration ramp.
[c]No dynamometer warm-up was performed prior to Test 11.

Table 7-6. Track Coastdown Data

Velocity Increment, km/h	Velocity Increment, mi/h	Average Velocity, km/h	Average Velocity, mi/h	Time Increment, s	"Smoothed" Time Increment, s
88.5 - 80.5	55 - 50	84.5	52.5	6.71	6.71
80.5 - 72.4	50 - 45	76.4	47.5	7.22	7.20
72.4 - 64.4	45 - 40	68.4	42.5	7.84	7.89
64.4 - 56.3	40 - 35	60.3	37.5	8.81	8.73
56.3 - 48.3	35 - 30	52.3	32.5	9.72	9.72
48.3 - 40.2	30 - 25	44.2	27.5	10.74	10.81
40.2 - 32.2	25 - 20	36.2	22.5	12.14	12.00
32.2 - 24.1	20 - 15	28.1	17.5	13.19	13.27
24.1 - 16.1	15 - 10	20.1	12.5	14.58	14.58

Table 7-7. Road Energy and Power

Velocity Increment, km/h	Velocity Increment, mi/h	Average Velocity, km/h	Average Velocity, mi/h	Energy, kWh/km	Energy, kWh/mi	Power, kW	Power, h
88.5 - 80.5	55 - 50	84.5	52.5	0.143	0.230	12.1	16.2
80.5 - 72.4	50 - 45	76.4	47.5	0.133	0.214	10.1	13.6
72.4 - 64.4	45 - 40	68.4	42.5	0.121	0.195	8.27	11.1
64.4 - 56.3	40 - 35	60.3	37.5	0.110	0.177	6.62	8.88
56.3 - 48.3	35 - 30	52.3	32.5	0.099	0.159	5.15	6.91
48.3 - 40.2	30 - 25	44.2	27.5	0.089	0.143	3.92	5.26
40.2 - 32.2	25 - 20	36.2	22.5	0.079	0.128	2.89	3.88
32.2 - 24.1	20 - 15	28.1	17.5	0.072	0.116	2.04	2.73
24.1 - 16.1	15 - 10	20.1	12.5	0.066	0.106	1.32	1.77

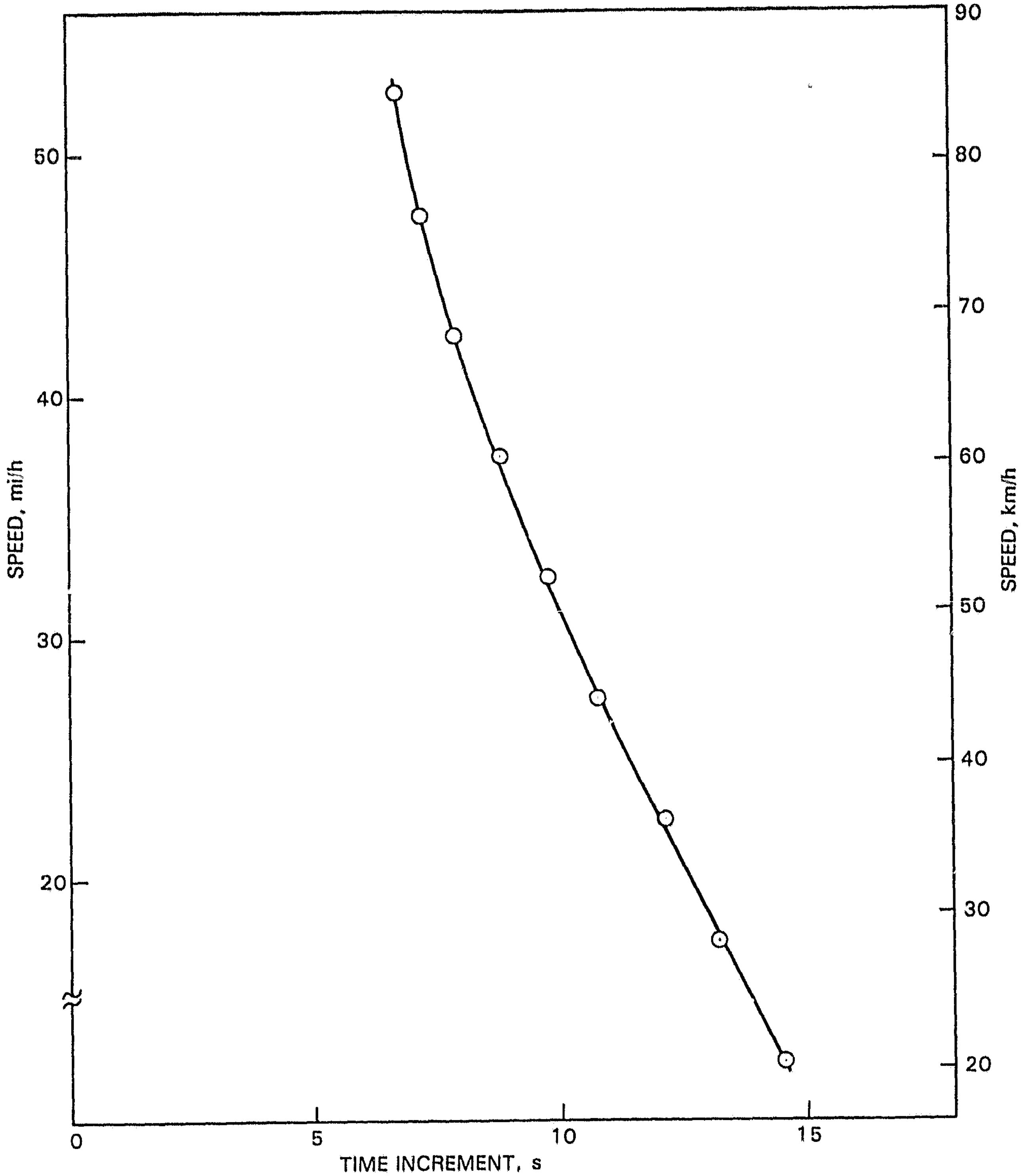

Figure 7-1. Average Speed vs Time Increment

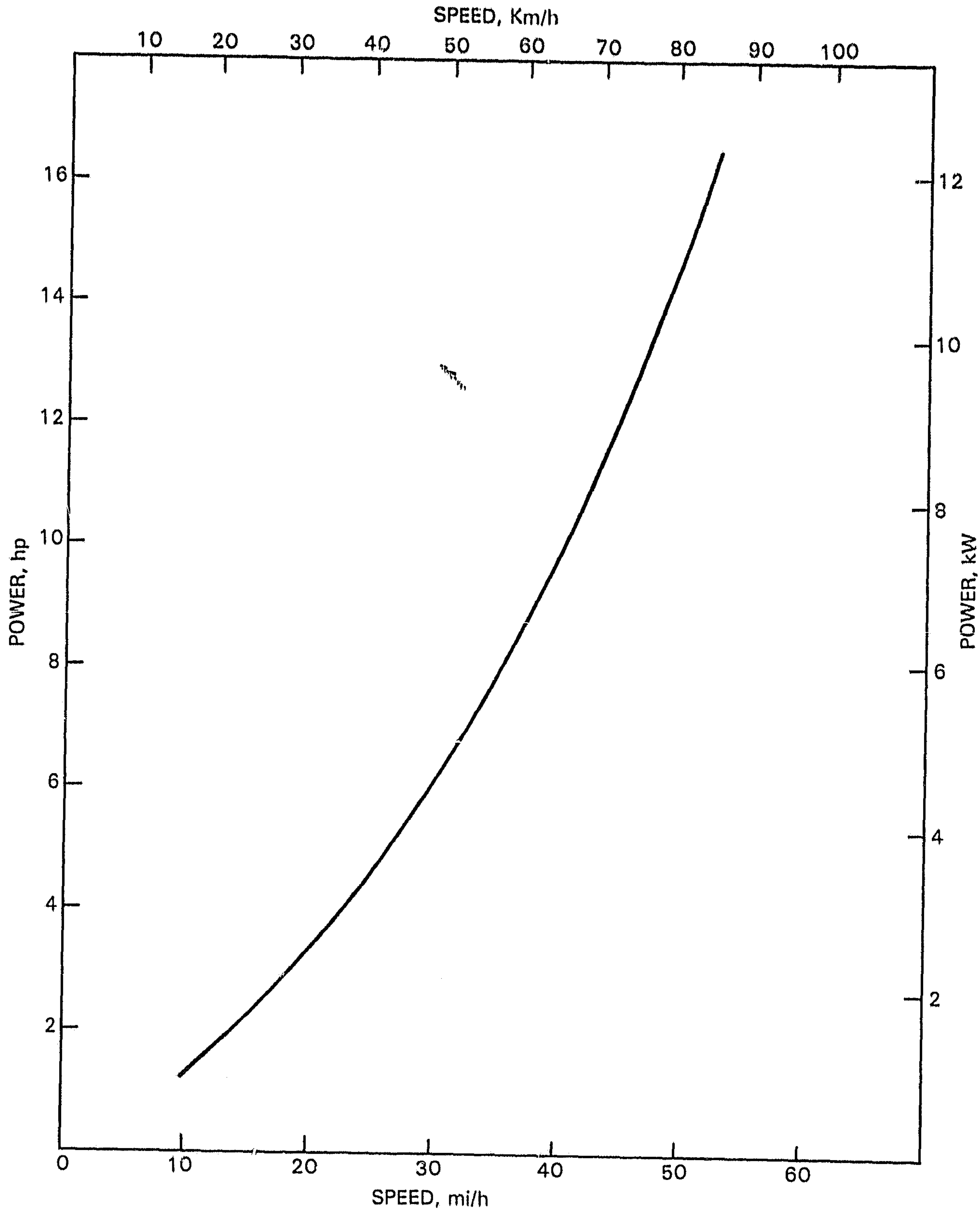

Figure 7-2. Road Power vs Speed

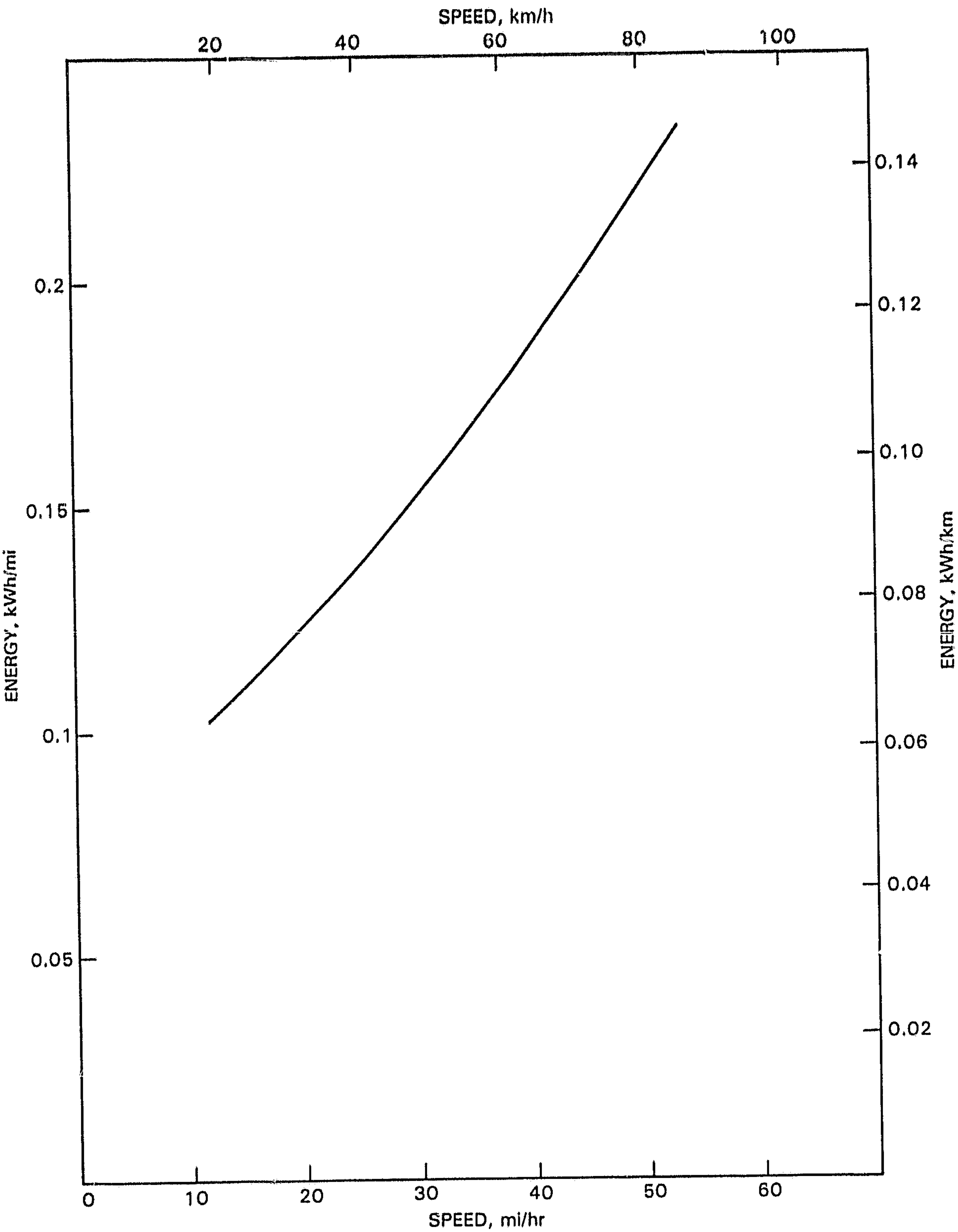

Figure 7-3. Road Energy vs Speed

SECTION VIII

DISCUSSION AND PROBLEMS

Presented in this section are observations concerning both the performance characteristics of the Electra Van 600 and some of the problems encountered during operation of the vehicle.

As an aid to understanding the characteristics of the Electra Van 600, energy usage was analyzed as a function of the five phases of the SAE J227a: procedure - acceleration, cruise, coast, brake, and idle. The energy divisions for a single B, C, and D driving cycle are depicted in Figures 8-1 through 8-3, respectively. The three cycles are compared directly in Figure 8-4 and the effect of battery depth of discharge is shown in Figures 8-5 and 8-6. An analysis comparable to that shown in Figures 8-5 and 8-6 was not attempted for the "D" cycle because of the limited test duration and associated difficulty in obtaining data as a function of depth of discharge (see page 5-2).

As would be expected for cyclic driving, over half the energy required by the Electra Van 600 goes into accelerating the vehicle. However, the vehicle makes effective use of the battery energy in the sense that almost all the energy is expended for motive purposes, and very little is used during the coast, brake, and idle periods. This is, of course, the direct result of a control strategy that uses an armature chopper. During periods when motive power is not needed, the system is "turned off" except for minor power users such as fans.

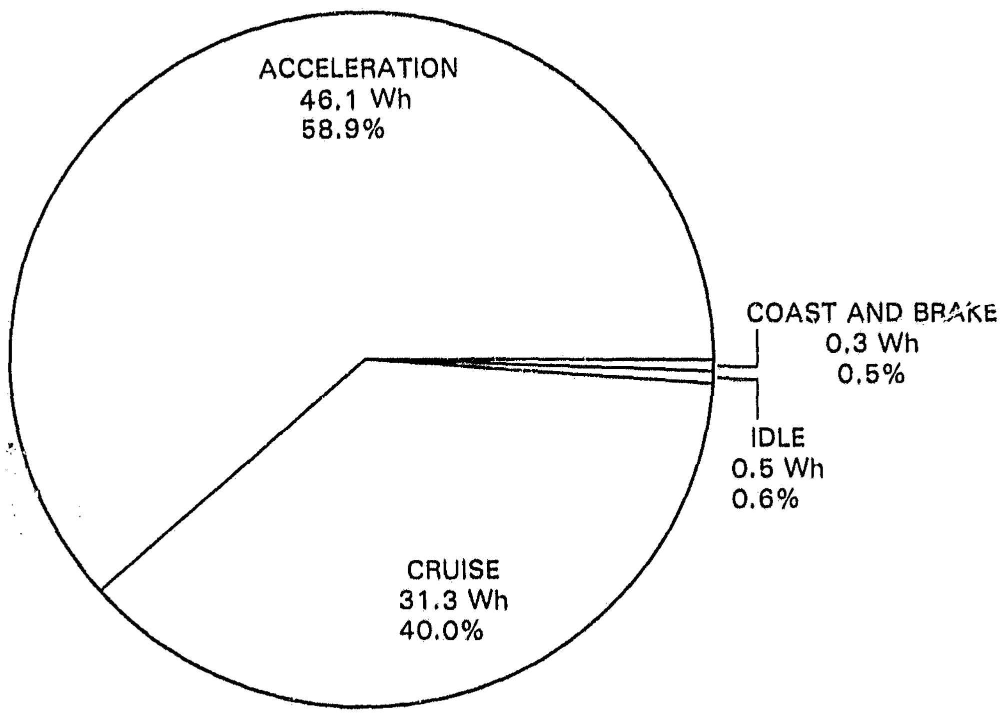

Figure 8-1. Electra Van 600 "B" Cycle Energy Split at 40% Depth of Discharge

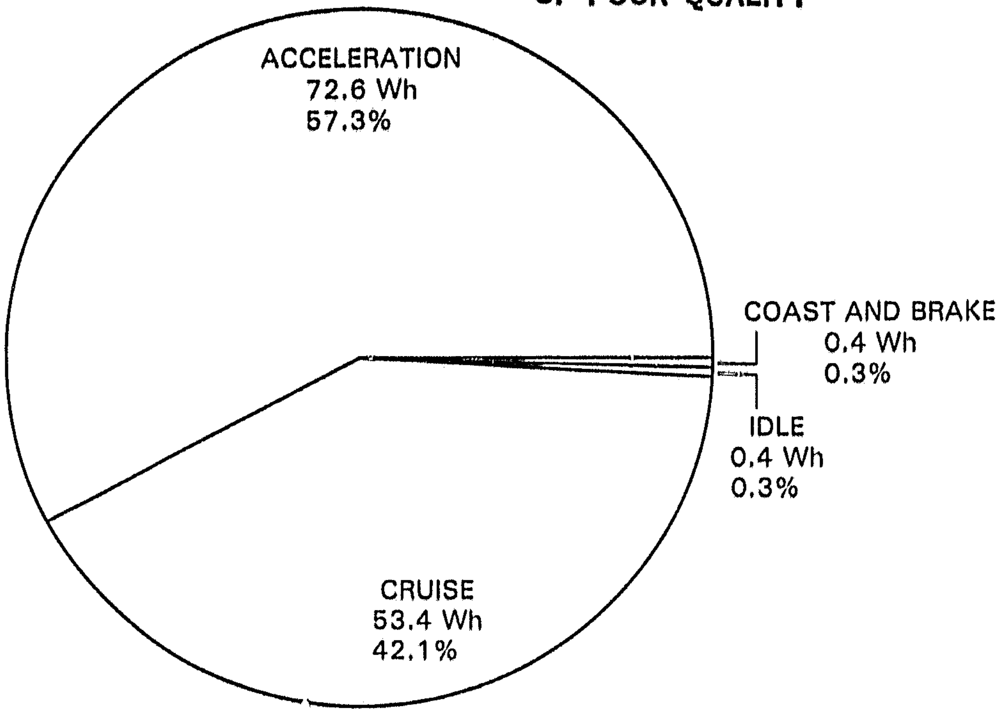

Figure 8-2. Electra Van 600 "C" Cycle Energy Split at 40% Depth of Discharge

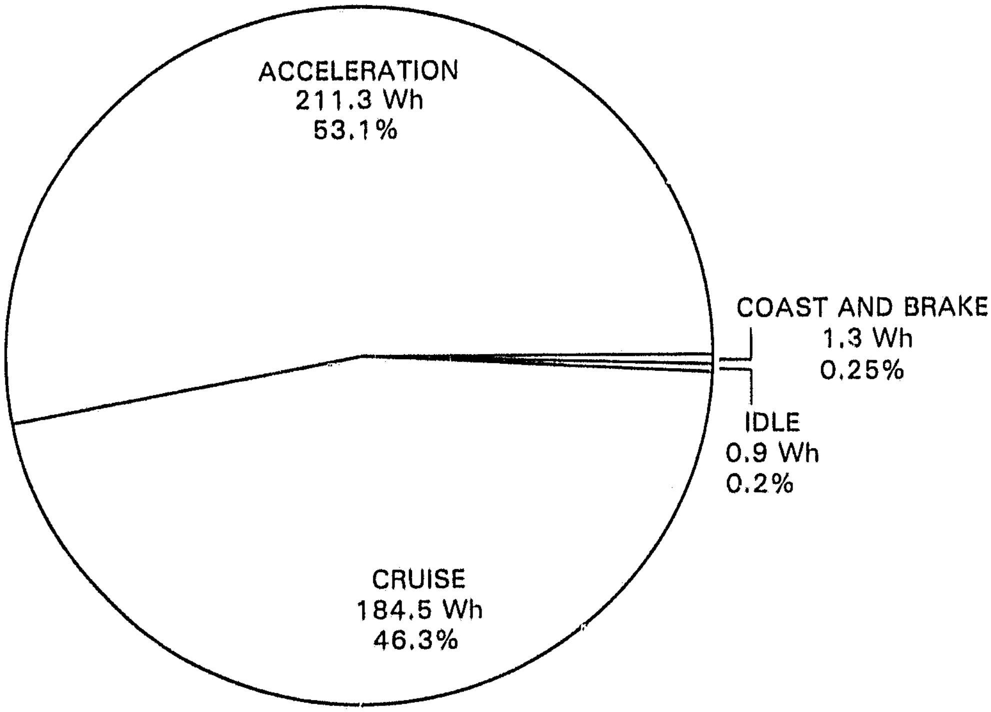

Figure 8-3. Electra Van 600 "D" Cycle Energy Split at 40% Depth of Discharge

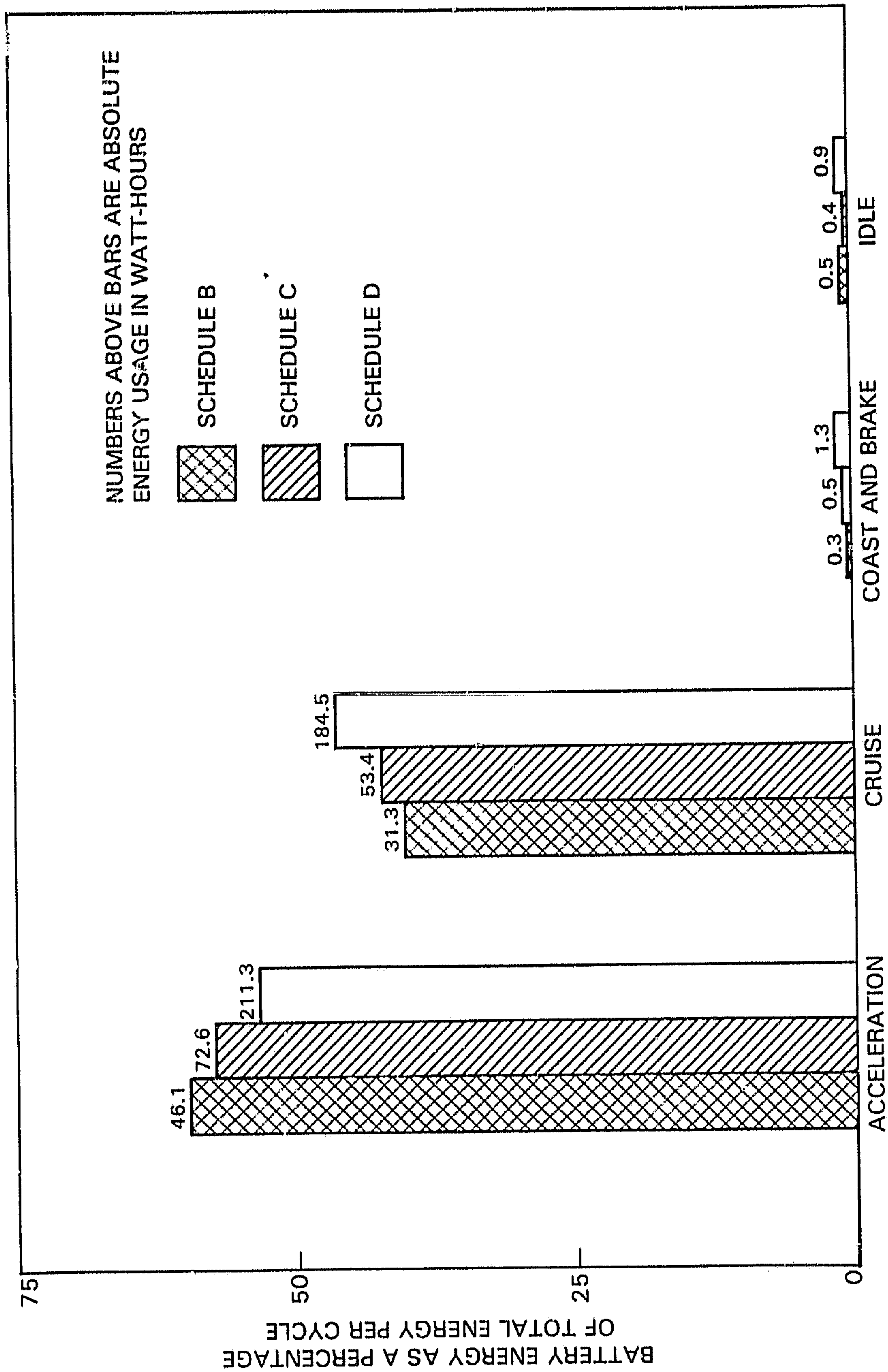

Figure 8-4. Comparison of Driving Schedules B, C, and D Energy Usage at 40% Depth of Discharge

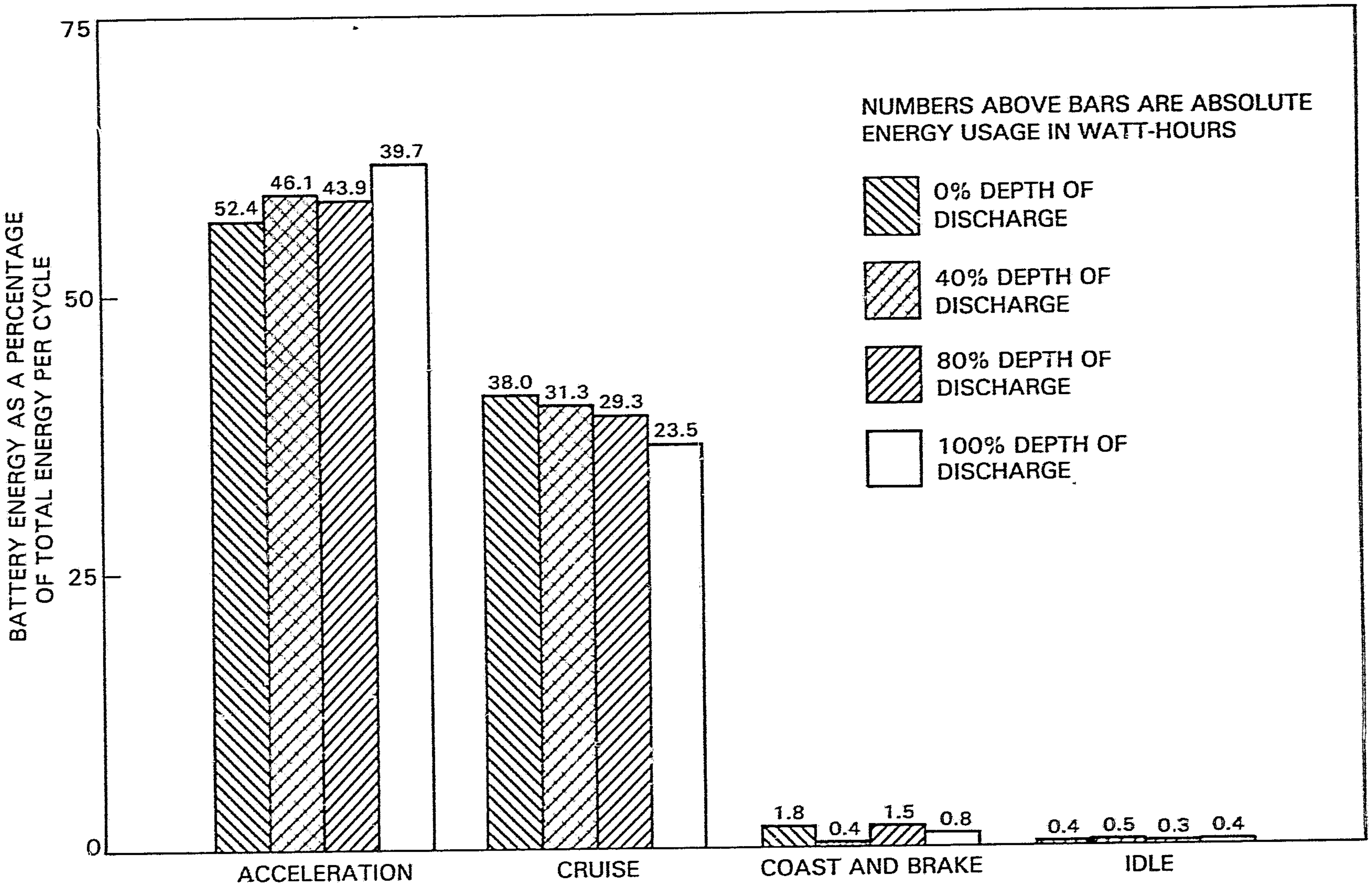

Figure 8-5. Schedule "B" Energy Usage as a Function of Battery Depth of Discharge

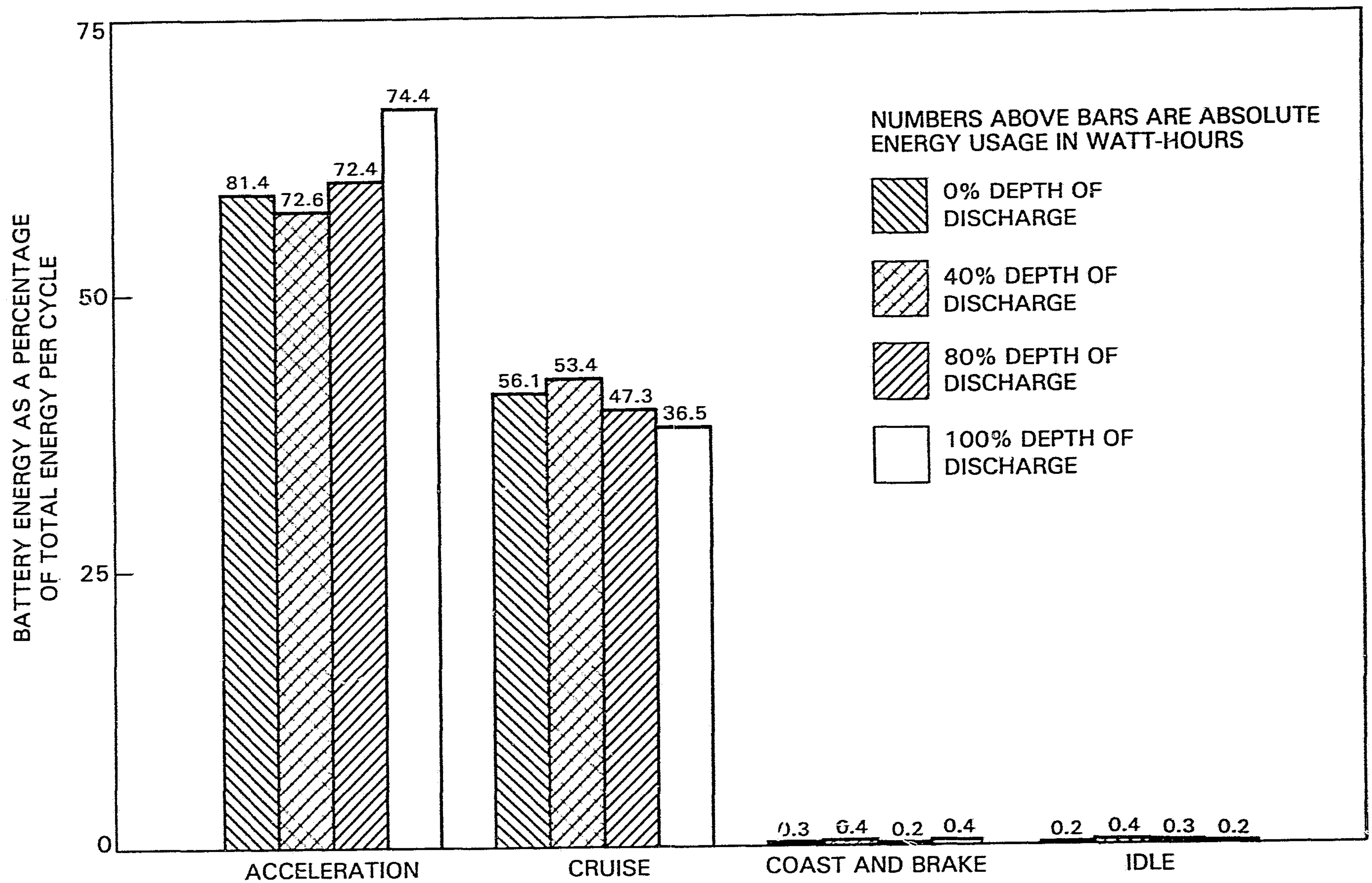

Figure 8-6. Schedule "C" Energy Usage as a Function of Battery Depth of Discharge

A qualitative evaluation of the Electra Van 600 has been made by comparing the performance described in this report with the results reported in Reference 8-1, which contains test results for 22 electric vehicles that were tested specifically for the purpose of assessing the state-of-the-art electric vehicles in 1977. Figure 8-7 consists of data from this report superimposed on a figure taken from the Reference 8-1 report.

Figure 8-7 is a plot of vehicle range versus vehicle speed for constant speed operation. The vehicles in Reference 8-1 fall into two general categories. The average for each of the two categories is denoted by a light, dashed line. The Electra Van 600 data is very nearly identical to the majority of the vehicles tested in 1977. It must be emphasized that the comparison shown in Figure 8-7 is qualitative, but at the same time it seems safe to conclude that the Electra Van 600 represents no particular performance advance over the 1977 state of the art.

After completing the track coastdown tests and after returning the Electra Van 600 to JPL, but before the dynamometer coastdowns began, the onboard charger failed. It was determined by Jet Industries that an incompatibility existed between the onboard charger and the SCR controller in that the controller was generating large negative voltage spikes on the battery charge line. The problem was corrected by the inclusion of a larger isolation diode in the onboard charger. No further problems were encountered with the onboard charger.

During the initial stages of the dynamometer performance tests, a vehicle temperature problem was encountered (see Tests 2 and 3, Table 7-3). This problem involved both the motor and controller and was eventually resolved by adding a second blower and ignoring the motor overtemperature warnings. These solutions evolved, in part, through discussions with the vehicle manufacturer. As originally configured, the vehicle had a single blower which provided parallel air sources for cooling of the controller and motor. In addition, included within the motor, is a fan for motor cooling. After re-configuration the original blower was dedicated to cooling the controller and a second, $100\text{-ft}^3/\text{min}$ blower was added by JPL for the motor. This action helped as far as the controller was concerned, but did not totally solve the controller problems and had little apparent effect on the motor problem.

A series of tests were conducted in which the power required of the motor was progressively increased and the motor overtemperature warning was ignored. For the highest loads attempted the motor stabilized at 161°C (322°F). The overtemperature warning occurred approximately at 127°C (260°F) (see page 4-1 for nominal conditions). After consultation with the motor manufacturer it appeared that the higher value should be acceptable. There have been no obvious deleterious effects during the subsequent performance tests in which the overtemperature warning was ignored. In addition, Jet Industries, after consultation with General Electric, modified the controller's protective circuitry so that current limiting would not occur until a temperature of 100°C (212°F). This allowed all subsequent performance tests to be continued until the battery was depleted.

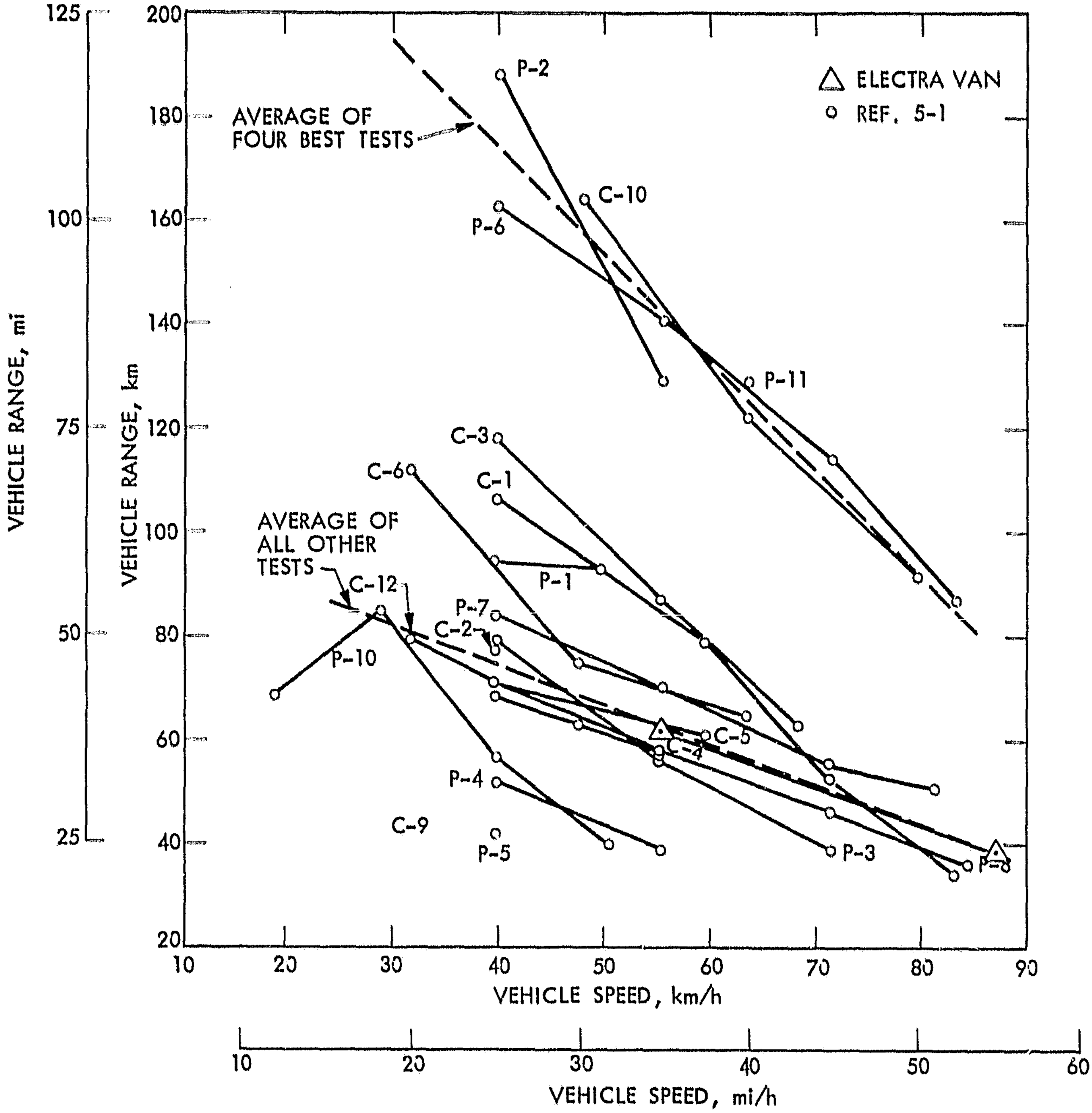

Figure 8-7. Vehicle Range as a Function of Speed

REFERENCES

2-1. Electric Vehicle Test Procedure - SAE J2272, Society of Automotive Engineers - Recommended Practice, February 1976.

5-1. Price, T. W., Shain, T. W., and Bryant, J. A., Vehicle Test Report: South Coast Technology Electric Conversion of a Volkswagen Rabbit, JPL Publication 81-28, Jet Propulsion Laboratory, Pasadena, California, February 1981.

5-2. Griffin, D. C., and Bryant, J. A., "Data Acquisition System for Electric Vehicle Tests," Proceedings of the IAS Annual Meeting, IEEE Industry Applications Society, September 1980.

8-1 State-of-the-Art Assessment of Electric and Hybrid Vehicles, NASA TM-73756, Lewis Research Center, Cleveland, Ohio, September 1977.

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APPENDIX

DATA SUMMARY FOR JET INDUSTRIES ELECTRA VAN 600
(JET VAN)

TEST NUMBERS	1	2	3	4	5	6	7	8
TEST DATE	06/29/79	07/02/79	07/05/79	07/13/79	07/16/79	08/09/79	10/23/79	10/24/79
TEST TYPE	COAST	B	B	B	35MPH	35MPH	35MPH	45MPH
BATTERY TYPE	PB-A	PB-A	PB-A	PB-A	PB-A	PB-A	PB-A	PB-A
BATTERY	SGL	SGL	SGL	SGL	SGL	SGL	SGL	SGL
BATTERY ENERGY ECONOMY (MI/KWH)	N.A.	2.64	2.69	2.75	3.61	3.71	N.A.	N.A.
RANGE (MILES)	N.A.	13.4	25.7	33.8	14.2	28.5	N.A.	35.4
BATTERY DISCHARGE ENERGY (KWH)	N.A.	5.06	9.6	12.29	3.93	7.69	N.A.	N.A.
BATTERY REGEN. ENERGY (KWH)	0.00	0.014	0.00	0.22	0.008	0.0007	0.00	0.00
BATTERY REGEN. ENERGY (%)	0.0	2.76	0.0	1.79	0.20	0.00509	0.0	0.0
BATTERY DISCHARGE (AMP - HOURS)	N.A.	55.9	104.3	139.2	43.7	85.1	N.A.	N.A.
BATTERY REGEN. (AMP - HOURS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BATTERY REGEN. AMPERAGE (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ARMATURE INPUT ENERGY (KWH)	N.A.	4.73	8.93	11.37	3.68	7.07	N.A.	N.A.
ARMATURE REGEN. OUTPUT (KWH)	0.00	0.633	0.00	0.10	0.0201	0.004	0.00	0.00
ARMATURE REGEN. OUTPUT (%)	0.0	0.0	0.0	0.87	0.0	0.0	0.0	0.0
FIELD ENERGY (KWH)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
CONTROLLER EFFICIENCY (%)	N.A.	93.4	93.3	92.5	93.0	91.9	N.A.	N.A.
ODOMETER READING (MILES)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
BATTERY RECHARGE ENERGY EFFICIENCY(%)	N.A.	47.58	56.73	61.50	N.A.	N.A.	N.A.	N.A.
BATTERY RECHARGE AMPERAGE EFFICIENCY(%)	N.A.	64.5	73.9	122.5	N.A.	N.A.	N.A.	N.A.
BATTERY TEMP. BEFORE (DEG F)	N.A.	71.3	72.1	74.4	72.6	79.0	78.6	93.8
BATTERY TEMP. AFTER (DEG F)	N.A.	80.0	82.8	92.8	80.4	93.4	N.A.	N.A.

* COMMENTS

TEST NO. 1: DATA NOT APPLICABLE

TEST NO. 2: INVALID RANGE TEST (MOTOR OVERHEATED)

TEST NO. 3: INVALID RANGE TEST (CONTROLLER OVERHEATED)

TEST NO. 4: FIRST VALID RANGE TEST

TEST NO. 5: INVALID RANGE TEST (MOTOR OVERHEATED)

TEST NO. 6: INVALID RANGE TEST (CONTROLLER OVERHEATED)

TEST NO. 7: INVALID RANGE TEST, NO IDAC DATA, DIAG. TEST ONLY

TEST NO. 8: INVALID RANGE TEST, NO IDAC DATA, DIAG. TEST ONLY

APPENDIX (CONT'D)

JET INDUSTRIES ELECTRA VAN 600 (JET VAN)

TEST NUMBERS	9	10	11	12	13	14	15	16
TEST DATE	01/11/80	01/14/80	01/16/80	01/18/80	01/21/80	01/23/80	01/25/80	01/28/80
TEST TYPE	H	35MPH	D	D	55MPH	35MPH	55MPH	C
BATTERY TYPE	PB-A	PB-A	PB-A	PB-A	PB-A	PB-A	PB-A	PB-A
BATTERY	SGL	SGL	SGL	SGL	SGL	SGL	SGL	SGL
BATTERY ENERGY ECONOMY (MI/KWH)	2,65	3,85	2,52	2,74	3,24	3,77	3,25	2,85
RANGE (MILES)	33.0	39.1	13,1	18,0	23.1	36.6	25,5	27.7
BATTERY DISCHARGE ENERGY (KWH)	12,44	10,15	5,19	6,56	7,12	9,71	7,84	9,71
BATTERY REGEN. ENERGY (KWH)	0,01	0,003	0,00	0,00	0,00	0,0002	0,00	0,06
BATTERY REGEN. ENERGY (%)	0,08	0,02	0,0	0,0	0,0	0,002	0,0	0,61
BATTERY DISCHARGE (AMP - HOURS)	137,8	116,6	58,7	75,2	79,5	109,4	86,9	113,8
BATTERY REGEN. (AMP - HOURS)	0,004	0,0	0,0	0,0	0,0	0,004	0,0	0,0
BATTERY REGEN. AMPERAGE (%)	0,002	0,0	0,0	0,0	0,0	0,003	0,0	0,0
ARMATURE INPUT ENERGY (KWH)	11,41	9,44	4,93	6,20	6,87	8,89	7,56	9,12
ARMATURE REGEN. OUTPUT (KWH)	0,02	0,0008	0,0004	0,00	0,00	0,00	0,00	0,005
ARMATURE REGEN. OUTPUT (%)	0,17	0,004	0,008	0,0	0,0	0,0	0,0	0,05
FIELD ENERGY (KWH)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
CONTROLLER EFFICIENCY (%)	91,7	93,0	94,9	94,5	96,4	91,5	96,4	93,9
ODOMETER READING (MILES)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
BATTERY RECHARGE ENERGY EFFICIENCY(%)	61,44	57,48	47,95	51,86	53,71	58,64	56,60	56,22
BATTERY RECHARGE AMPERAGE EFFICIENCY(%)	76,8	77,4	65,4	70,4	71,6	77,5	74,1	77,1
BATTERY TEMP. BEFORE (DEG F)	71,0	70,4	74,8	70,6	69,8	71,2	74,0	67,6
BATTERY TEMP. AFTER (DEG F)	88,9	67,6	83,6	88,8	82,2	90,2	90,4	92,8

* COMMENTS

APPENDIX (CONT'D)

JET INDUSTRIES ELECTRA VAN 600 (JET VAN)

TEST NUMBERS	17
TEST DATE	01/30/80
TEST TYPE	C
BATTERY TYPE	PB-A
BATTERY	SGL
BATTERY ENERGY ECONOMY (MI/KWH)	2.85
RANGE (MILES)	29.3
BATTERY DISCHARGE ENERGY (KWH)	10.28
BATTERY REGEN. ENERGY (KWH)	0.006
BATTERY REGEN. ENERGY (%)	0.05
BATTERY DISCHARGE (AMP - HOURS)	116.0
BATTERY REGEN. (AMP - HOURS)	0.0
BATTERY REGEN. AMPERAGE (%)	0.0
ARMATURE INPUT ENERGY (KWH)	9.53
ARMATURE REGEN. OUTPUT (KWH)	0.002
ARMATURE REGEN. OUTPUT (%)	0.02
FIELD ENERGY (KWH)	N.A.
CONTROLLER EFFICIENCY (%)	92.7
ODOMETER READING (MILES)	N.A.
BATTERY RECHARGE ENERGY EFFICIENCY(%)	58.82
BATTERY RECHARGE AMPERAGE EFFICIENCY(%)	76.1
BATTERY TEMP. BEFORE (DEG F)	71.2
BATTERY TEMP. AFTER (DEG F)	96.2

* COMMENTS